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US 4607529 A US 4482859 A US 4352293 A
US 3938394 A US 3488581 A

(58) Field of Search
UK CL (Edition O) G1N NCTD NCTE NCTL NCTM NCXB
INT CL^6 G01B, G01H
Online: WPI

(54) **Method and apparatus for analysing variations in rotary motion**

(57) A method and apparatus for analysing variations in rotary motion e.g of a turbine assembly T utilises a capacitive probe P whose frequency modulated output signal is detected by a phase locked loop detector 2 and analysed by a digital sampling circuit 3 which fits a fourth order polynomial to a group of successive digitised signals representative of the instantaneous distance between a given turbine blade B and the probe P as the blade passes the probe. The peak amplitude of the fitted curve varies with time, i.e. from revolution to revolution in a periodic manner and this time dependent peak amplitude is subjected to a Fourier transform in order to detect frequency components which are due, e.g. to orbital and vibrational motion of the turbine assembly.

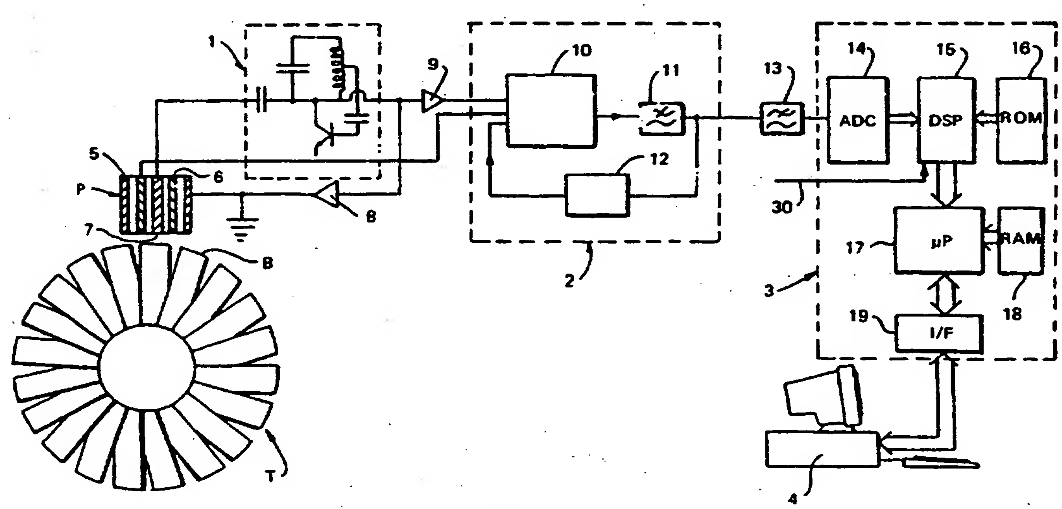

FIG. 1

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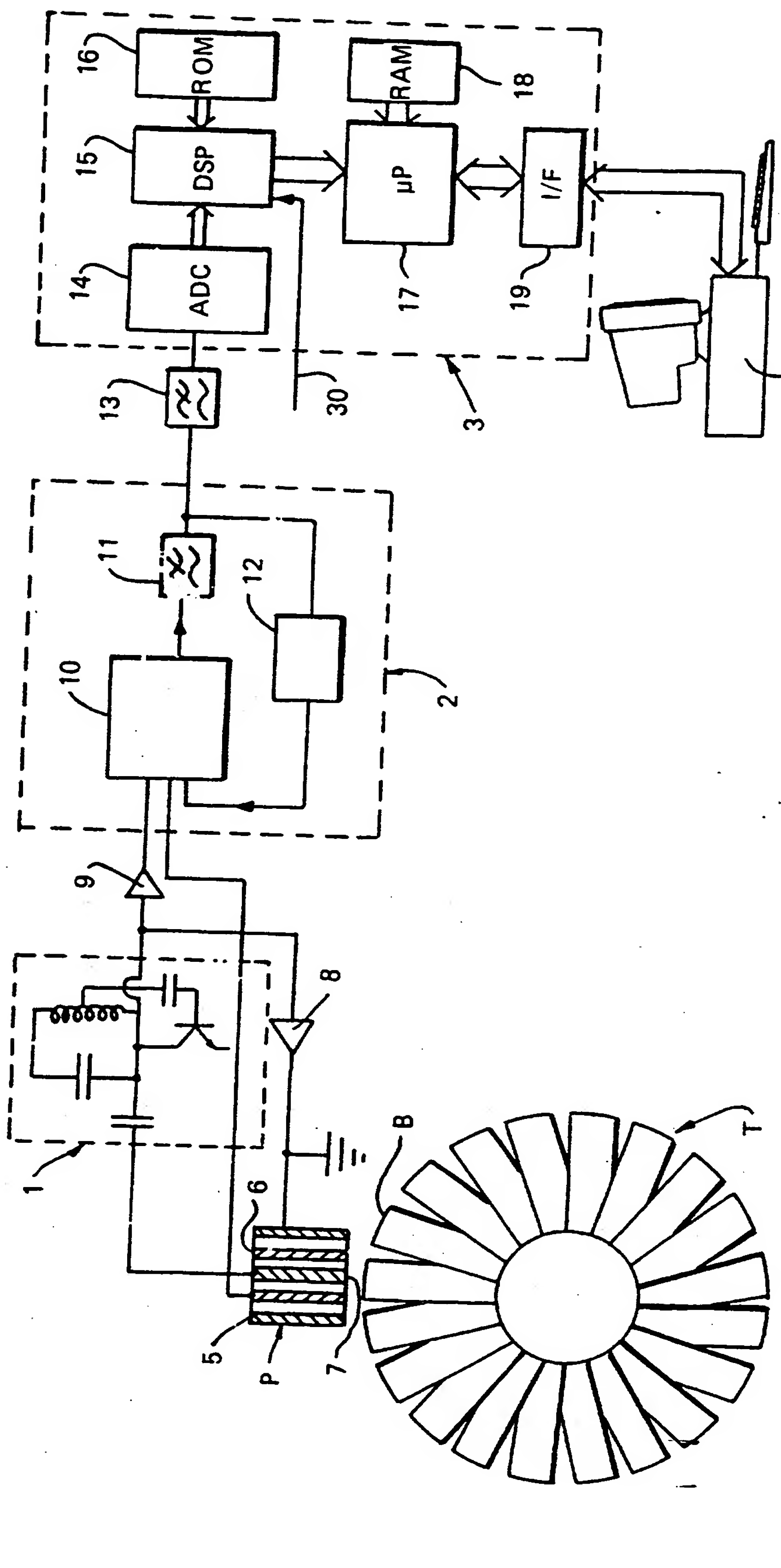
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


ROM
DSP
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µP
I/F
1
2
3
4
5
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13
14
15
16
17
18
19
30
B
T
P

FIG. 1

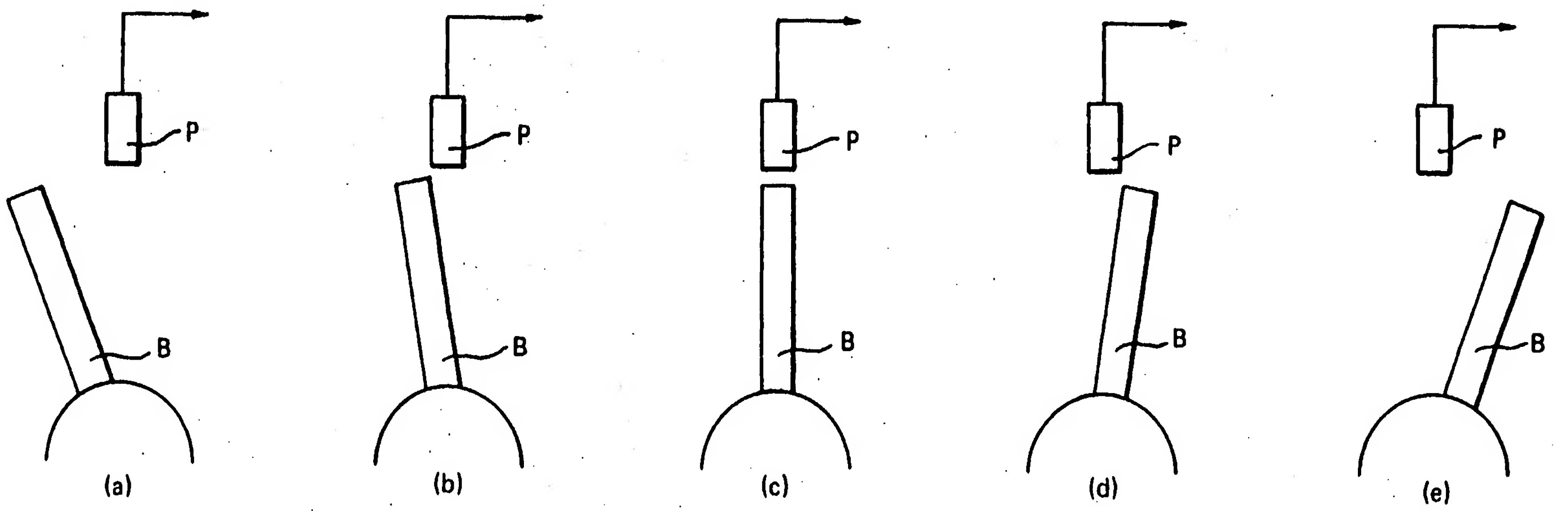

FIG. 2

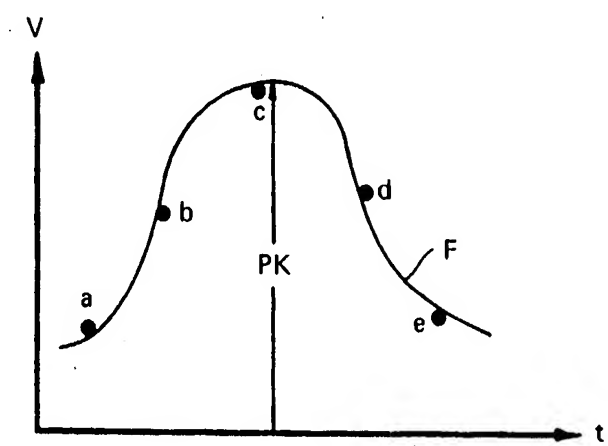

FIG. 3

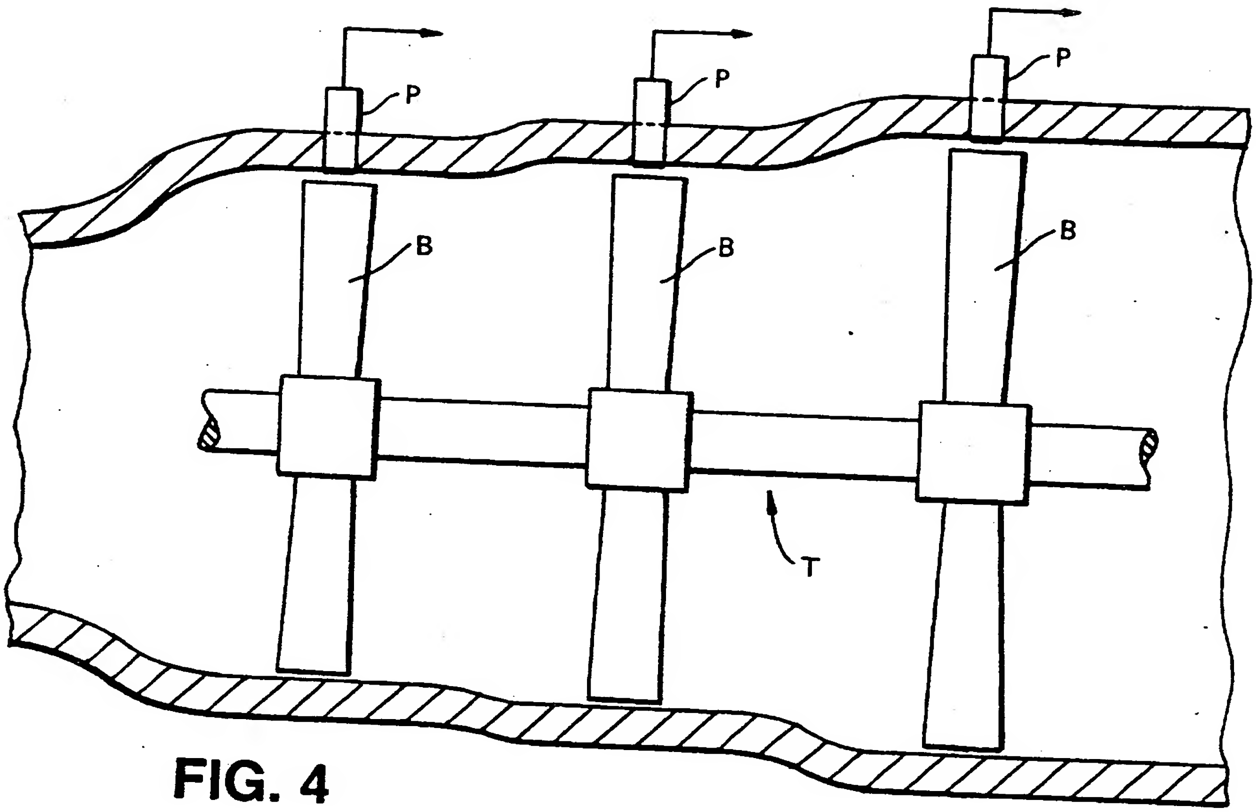

FIG. 4

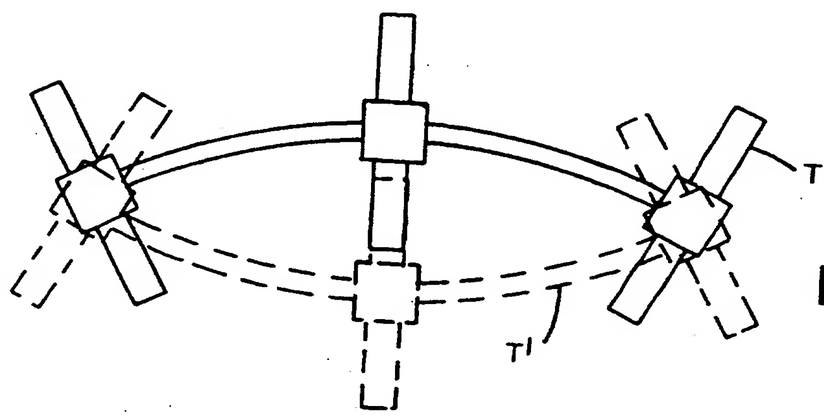

FIG. 5

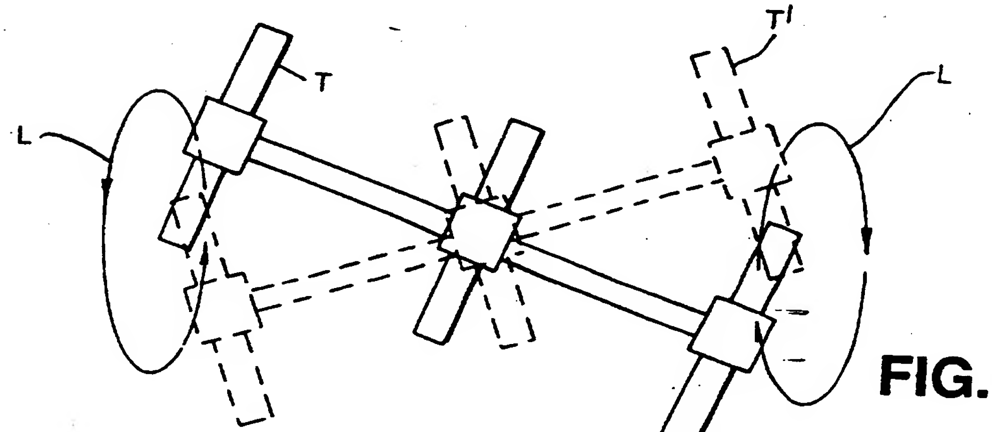

FIG. 6

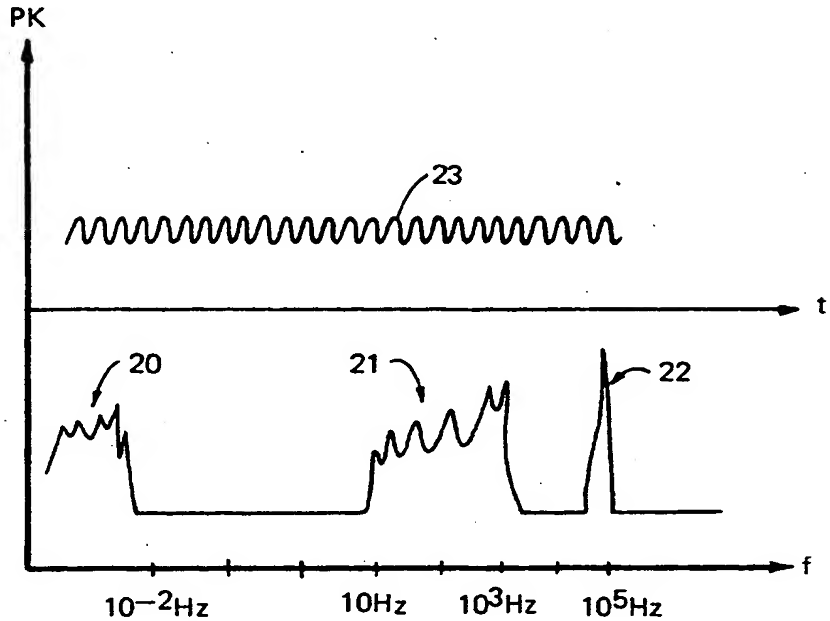
PK
23
t
20
21
22
f
10^{-2}Hz
10Hz
10^3Hz
10^5Hz

FIG. 7

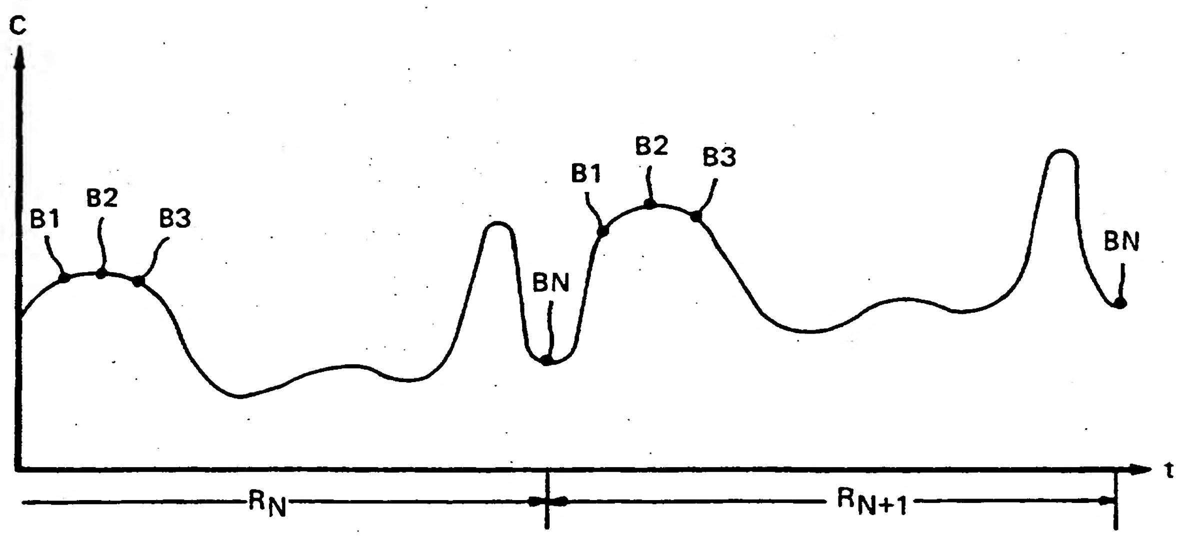
C
B1
B2
B3
BN
B1
B2
B3
BN
t
R_N
R_{N+1}

FIG. 8

ANALYSIS OF MOTION OF ROTARY ASSEMBLY

The present invention relates to a method and apparatus for analysing variations in the motion of a rotary assembly particularly but not exclusively variations in the motion of a turbine assembly.

It is known to utilise a capacitive probe to detect the individual clearances of the tips of turbine blades from the interior or the casing. However, it is difficult to derive any further information from conventional systems of this nature, in particular owing to the noise inherent in the probe output signals.

An object of the present invention is to provide a method and apparatus capable of deriving information about variations in the motion of a rotary assembly from variations in detected clearance signals.

In one aspect the present invention provides a method of analysing variations in the motion of a rotary assembly, the method comprising repeatedly detecting the clearance between a rotating element of said assembly and a datum, generating clearance signals which are a function of said clearance, analysing said signals to derive frequency components attributable to such variations, and deriving information about such variations from the phase and/or amplitude of said frequency components.

In another aspect the invention provides apparatus for analysing variations in the motion of a rotary assembly the apparatus comprising a probe means arranged to repeatedly detect the clearance from a rotating element of said rotary assembly and to generate

clearance signals which are a function of said clearance, Fourier transform analysing means responsive to such signals to derive frequency components attributable to such variations, and processing means arranged to derive information about such variations from the phase and/or amplitude of said frequency components.

Preferably, the clearance signal is derived from digital signals which are generated successively as a discrete rotating element moves past the probe (at the datum position), each digital signal being a function of the instantaneous distance between that discrete rotating element and the probe (datum position).

In a preferred embodiment the clearance signal is derived by fitting a function of predetermined form to the digital signals and then determining a peak amplitude of the function. This leads to the advantage that the effects of noise are largely eliminated, so that the peak amplitude and hence the clearance can be accurately determined. Because the clearance can be accurately determined, periodic variations in the clearance can also be accurately determined, e.g. by a Fourier transform. In particular, it has been found that orbiting motion of a turbine shaft, (e.g. due to play in the bearings) can be detected, as well as motion due to vibration of turbine blades or the shaft.

Preferred features of the invention are defined in the dependant Claims.

Preferred embodiments of the invention will now be described with reference to Figures 1 to 8 of the accompanying drawings wherein:

Figure 1 is a block diagram of apparatus in accordance with the invention;

Figure 2 is a diagrammatic representation of a turbine blade moving past a capacitive probe;

Figure 3 is a plot of the digital output signals obtained in the various rotary positions of the turbine blade in Figure 2;

Figure 4 is a schematic sectional view of a further probe arrangement for use in the method and apparatus of the invention;

Figure 5 is a diagrammatic side elevation showing shaft vibration detectable by the method and apparatus of the invention;

Figure 6 is a schematic side elevation showing orbital motion detectable by a method and apparatus of the invention; and

Figure 7 shows a plot of the clearance signal against time and the Fourier transform thereof; and

Figure 8 is a plot of blade clearance: time showing the variation in the pattern of blade clearances between revolutions N and N+1.

Referring to Figure 1, the turbine assembly T is shown end-on, with a capacitive probe P located in the casing (not shown) closely adjacent the periphery of the turbine blades B. The probe P is of generally cylindrical form and comprises a central element 7 which is

surrounded by first shield 6 which is in turn surrounded by a further cylindrical shield 5. The central element 7 and cylindrical shield 6 are connected to an oscillator circuit 1 and variations in the capacitance between shield 6 and element 7 due to the passage of turbine blades B past probe P cause corresponding variations in the resonant frequency of the oscillator circuit 1. Hence the output of this circuit is a frequency modulated signal which is transmitted via a buffer amplifier 9 to a detector circuit 2. In order to isolate the detected probe capacitance from noise and external stray fields a buffer amplifier 8 with a gain slightly less than unity (e.g. 0.98) feeds the output signal back to external shield 5. This shield is earthed.

The output signal from buffer 9 is a frequency modulated signal, the variations in frequency being proportional to the changes in capacitance caused by the passage of blades B passed the probe P. Hence, the frequency variation is a function of the instantaneous distance of the tip of the nearest turbine blade B from the surface of probe P. Accordingly, the frequency modulated signal is fed to an input of a phase comparator 10 where it is compared in frequency with a signal from a voltage-controlled oscillator 12. Oscillator 12 is located in a phase-locked loop and controlled by an output voltage from discriminator 10 which is filtered through a low pass filter 11. This filtered output is, therefore, a DC signal whose instantaneous voltage is inversely related to the instantaneous clearance between the tip of a turbine blade B from probe P as the turbine blade passes the probe.

Such a signal will inevitably have a significant noise component which tends to prevent an accurate estimate of the clearance, (i.e. the minimum distance between the tip of a turbine blade) and the probe from being determined. However, in accordance with the

present invention this signal is fed through a further low pass filter 13 to a digital processing circuit 3 comprising a high speed analogue-to-digital converter 14 which samples the signal typically at a rate of 4 MHz. The analogue-to-digital converter 14 may, for example, be a MAX176 converter which produces a multiplicity of successive 12 bit output signals as any given blade B passes probe P. The digital signals corresponding to the traverse of one blade B are fitted to a fourth order polynomial having specified coefficients in a digital signal processor 15 which may be an AD2181 processor for example. In order to separate the groups of signals corresponding to respective turbine blades B a counting signal, e.g. from a tachogenerator coupled to the turbine assembly T is fed to the digital signal processor. Alternatively, the probe P can be arranged to detect the arrival of each successive blade B. The required polynomial and curve-fitting software are stored in a ROM 6 and the processing is controlled by a microprocessor 17 (which may be a 68020 type for example) under the control of a program stored in RAM 18. A serial interface 19 is coupled to microprocessor 17 and enables control signals to be fed to the processor 3 from a terminal 4, which is also arranged to display the results of the curve-fitting, namely the clearance of each blade B from probe P and the time variations in such clearances.

As will subsequently be explained in more detail, microprocessor 17 is arranged to apply a Fourier transformer to at least one (and preferably all) of the blade clearances as determined by the above described curved-fitting process. These clearances vary with time, owing e.g. to orbital motion of the shaft and vibrational motion of the shaft and turbine blades and the amplitude and also the phase of such variations can be determined as will subsequently be explained in more detail with reference to Figure 7. At this stage, it should, however, have been noted that the cause of the detected

variations in clearance can be determined from their frequency and from a rough knowledge of the mechanical properties of the turbine.

The curved-fitting process will now be described in more detail with reference to Figures 2 and 3. Figure 2 shows a single turbine blade B in five positions (a) to (e) as it rotates past a probe P. At the corresponding instants the instantaneous digital signal generated by analogue-to-digital converter 14 is as shown by points (a) to (e) respectively in Figure 3. Typically, in practice there will be 128 digital signals generated as each blade passes the probe. However sufficiently accurate results may be obtained from few signals. In theory, the above digital signals should exactly fit a curve of a predetermined form (determined by the characteristics of the probe, oscillator circuit and the profile of the blade B), but in practice the precursor analogue signals will be contaminated by noise leading to some inaccuracy. In accordance with a preferred feature of the invention, this inaccuracy is substantially eliminated by fitting a curve described by a polynomial to these points as illustrated at F in Figure 3. The peak amplitude PK of this curve will, therefore accurately represent the clearance, i.e. the minimum distance between the particular turbine blade B illustrated in Figure 2 and the probe P. As previously noted this peak amplitude will vary from revolution to revolution, owing to variations in the rotation of the shaft due, e.g. to orbital and vibratory motion. Because the peak amplitude PK can be accurately determined at any revolution, its variations due to such motion can also be accurately determined, even when they are very small in comparison with the average clearances.

Detection of vibratory and orbitary motion will now be described in more detail with reference to Figures 4 to 6. Figure 4 shows a turbine assembly T having three arrays of

turbine blades B and three probes P aligned with the respective arrays. Each probe P can be coupled to its own oscillator circuit 1, detector circuit 2 and processor circuit 3 as illustrated in Figure 1, but alternatively a common digital processor circuit 3 may process the detected signals from all three probes P. In either case, the results are displayed on the display of a terminal 4. By carrying out the analysis described above with reference to Figure 2 and 3, variations in the peak amplitude PK as illustrated by the upper plot 23 in Figure 7 are determined and the resulting Fourier analysis illustrated by the lower plot in Figure 7 reveals various vibration spectra 20,21 and 22 of which the components 21 in the frequency range of approximately 10 Hz to 2 kHz are due to orbiting or nutation of the rotor as illustrated by loci L in Figure 6 and by vibration of the turbine axle as illustrated in Figure 5. In both Figures 5 and 6, the extreme positions of the turbine assembly are shown in grossly exaggerated form. Confirmation of the frequency component which is due to vibration of the turbine axle as shown in Figure 5 can be obtained by comparing the phase of the signal from the central probe P of Figure 4 with the phase of the output from the end probes P shown in this Figure. As is apparent from Figure 5, the output of the central probe is approximately in anti-phase with the output of the end probes. In general, information about variations in the motion of the turbine assembly can be derived from the phase and/or amplitude of real and imaginary Fourier transforms of the plot 23 shown in Figure 7. In Figure 7 only the real component of the Fourier transform is shown.

It should be noted that the description of the embodiment of Figures 3 to 7 has related to detection of variations in the clearance of a single blade over time. As shown above, analysis of this variation enables, e.g. orbital motion of the shaft to be detected and its amplitude and frequency determined.

However much greater accuracy is achievable if the clearance C of two, three, four or more (preferably all) of the blades B1,B2,B3 .... BN is detected by the method and apparatus described above. The resulting plot during successive revolutions R_N and R_{N+1} is shown in Figure 8 and it will be seen that a repeating pattern of blade clearances is exhibited. This pattern reflects the variations in length or radial position of the individual blades. Any orbiting of the shaft will result in a vertical shifting of this pattern from revolution to revolution, as shown. By comparing the average clearance during rotation R_N with the average clearance during rotations R_{N+1}, R_{N+2} ....etc., accurate date on the motion of the notary turbine assembly as a whole can be obtained.

It should be noted that the probe P and its oscillator circuit 1 as shown in Figure 1 are known per se. The actual distance between the tip of a turbine blade and the facing surface of the probe P can be correlated with a detected change in capacitance and hence a detected change in frequency by a calibration process involving advancing the probe P by a known amount towards the turbine blades B. It is known that the distance and hence the capacitance change (or frequency change) can be closely approximated by a second order function of the form:

$$\Delta = C_1 + \frac{C_2}{(\Delta + 0.2)} + \frac{C_3}{(\Delta + 0.3)^2}$$

where Δ is the change in capacitance (or frequency), and C1, C2 and C3 are coefficients which are determined by the best curve fit.

In accordance with a further aspect of the invention a capacitive probe is utilised to detect the clearance from non-metallic blades. Preferably the non-metallic turbine blades are however metallised, e.g. by plating or vacuum disposition of a suitable metal. Optionally, some other conductive material can be deposited, e.g. carbon. In order to protect the surface of the probe P facing the turbine blades B, a glass or silicate material can be used as a surface coating on the probe P. Such materials are relatively soft at the temperatures employed in turbines and therefore protect the turbine blades against damage.

The detection of the clearance from non-metallic blades can optimally be carried out in conjunction with the novel method of analysing variations in rotary motion in accordance with the invention.

CLAIMS

1. A method of analysing variations in the motion of a rotary assembly, the method comprising repeatedly detecting the clearance between a rotating element of said assembly and a datum, generating clearance signals which are a function of said clearance, analysing said signals to derive frequency components attributable to such variations, and deriving information about such variations from the phase and/or amplitude of said frequency components.

2. A method according to Claim 1 wherein a multiplicity of successive digital signals are generated as a discrete rotating element of said rotary assembly moves past a datum position, each digital signal being a function of the instantaneous distance between that discrete rotating element and said datum position, and said clearance signal is derived from said digital signals.

3. A method according to Claim 2 wherein a further multiplicity of successive digital signals are generated as a further discrete rotating element of said rotary assembly moves past said datum position or as the first-mentioned discrete rotating element moves past a further datum position and a further clearance signal which is a function of the clearance of said further discrete element from said datum position or the clearance of said first-mentioned discrete element from said further datum position is generated from said further multiplicity of digital signals.

4. A method according to Claim 3 wherein both said clearance signals are analysed to derive said frequency components.

5. A method according to Claim 4 wherein said discrete rotating elements and/or datum positions are spaced apart in the axial direction.

6. A method according to any of Claims 2 to 5 wherein said clearance signal is derived by fitting a function of predetermined form to said digital signals and then determining a peak amplitude of the function.

7. A method according to Claim 6 wherein said function of predetermined form is a polynomial of predetermined order.

8. A method according to Claim 7 wherein said function of predetermined form is a polynomial having predetermined coefficients.

9. A method according to Claim 7 or Claim 8 wherein said polynomial is a fourth order polynomial.

10. A method according to any preceding Claim wherein orbiting or shaft bending motion of the rotary assembly is detected.

11. A method according to any of Claims 2 to 9 wherein bending of said discrete element is detected.

12. A method according to any preceding Claim wherein said clearance signal is generated by a capacitive probe.

13. A method according to any preceding Claim wherein a frequency modulated signal is generated whose frequency is a function of the instantaneous distance between its rotating element and datum, and frequency variations in said frequency modulated signal are detected by a phase-locked loop detector, said clearance signal being derived from an output signal of said detector.

14. A method according to any preceding Claim wherein said rotary assembly is a turbine assembly.

15. Apparatus for analysing variations in the motion of a rotary assembly, the apparatus comprising a probe means arranged to repeatedly detect the clearance from a rotating element of said rotary assembly and to generate clearance signals which are a function of said clearance, Fourier transform analysing means responsive to such signals to derive frequency components attributable to such variations, and processing means arranged to derive information about such variations from the phase and/or amplitude of said frequency components.

16. Apparatus according to Claim 15 comprising digital sampling means arranged to generate a plurality of digital signals which are a function of the instantaneous distance of a discrete rotating element of said rotary assembly from the probe means and digital processing means arranged to derive said clearance signal

from said digital signals by fitting a function of predetermined form to said digital signals and then determining a peak amplitude of the function.

17. Apparatus according to Claim 16 wherein said function is as defined in any of Claims 7 to 9.

18. Apparatus according to any of Claims 15 to 17 wherein said probe means is a capacitive probe.

19. Apparatus according to Claim 18 wherein said capacitive probe is coupled to an oscillator circuit which is arranged to generate a frequency-modulated output signal and a phase-locked loop detector is arranged to generate a further output signal which is a function of frequency variations in said first-mentioned output signal.

20. A method of analysing variations in the motion of a rotary assembly substantially as described hereinabove with reference to Figures 1 to 3 optionally as modified in accordance with any of Figures 4 to 7 of the accompanying drawings.

21. Apparatus for analysing variations in the motion of a rotary assembly substantially as described hereinabove with reference to Figures 1 to 3 optionally as modified in accordance with any of Figures 4 to 7 of the accompanying drawings.

Amendments to the claims have been filed as follows

1. A method of analysing variations in the motion of a rotary assembly, the method comprising repeatedly detecting the clearance between a discrete rotating element of said assembly and a datum, generating clearance signals which are a function of said clearance, analysing said signals to derive frequency components attributable to such variations, and deriving information about such variations from the phase and/or amplitude of said frequency components, wherein a multiplicity of successive digital signals are generated as a discrete rotating element of said rotary assembly moves past a datum position, each digital signal being a function of the instantaneous distance between that discrete rotating element and said datum position, and said clearance signal is derived from said digital signals.

2. A method according to Claim 1, wherein a further multiplicity of successive digital signals are generated as a further discrete rotating element of said rotary assembly moves past said datum position or as the first-mentioned discrete rotating element moves past a further datum position and a further clearance signal which is a function of the clearance of said further discrete element from said datum position or the clearance of said first-mentioned discrete element from said further datum position is generated from said further multiplicity of digital signals.

3. A method according to Claim 3 wherein both said clearance signals are analysed to derive said frequency components.

4. A method according to Claim 4 wherein said discrete rotating elements and/or datum positions are spaced apart in the axial direction.

5. A method according to any of Claims 2 to 5 wherein said clearance signal is derived by fitting a function of predetermined form to said digital signals and then determining a peak amplitude of the function.

6. A method according to Claim 6 wherein said function of predetermined form is a polynomial of predetermined order.

7. A method according to Claim 7 wherein said function of predetermined form is a polynomial having predetermined coefficients.

8. A method according to Claim 7 or Claim 8 wherein said polynomial is a fourth order polynomial.

9. A method according to any preceding Claim wherein orbiting or shaft bending motion of the rotary assembly is detected.

10. A method according to any of Claims 2 to 9 wherein bending of said discrete element is detected.

11. A method according to any preceding Claim wherein said clearance signal is generated by a capacitive probe.

12. A method according to any preceding Claim wherein a frequency modulated signal is generated whose frequency is a function of the instantaneous distance between its rotating element and datum, and frequency variations in said frequency modulated signal are detected by a phase-locked loop detector, said clearance signal being derived from an output signal of said detector.

13. A method according to any preceding Claim wherein said rotary assembly is a turbine assembly.

14. Apparatus for analysing variations in the motion of a rotary assembly, the apparatus comprising a probe means arranged to repeatedly detect the clearance between a discrete rotating element of said rotary assembly and a datum and to generate clearance signals which are a function of said clearance, Fourier transform analysing means responsive to such signals to derive frequency components attributable to such variations, and processing means arranged to derive information about such variations from the phase and/or amplitude of said frequency components, said apparatus including digital sampling means arranged to generate a plurality of digital signals which are a function of the instantaneous distance of a discrete rotating element of said rotary assembly from the probe means and digital processing means arranged to derive said clearance signal from said digital signals.

15. Apparatus according to claim 14 wherein said digital processing means is arranged to derive said clearance signal from said digitial signals by fitting a cuntion of predetermined form to said digital signals and then determining a peak amplitude of the function.

16. Apparatus according to Claim 15 wherein said function is as defined in any of Claims 6 to 8.

17. Apparatus according to any of Claims 14 to 16, wherein said probe means is a capacitive probe.

18. Apparatus according to Claim 17, wherein said capacitive probe is coupled to an oscillator circuit which is arranged to generate a frequency-modulated output signal and a phase-locked loop detector is arranged to generate a further output signal which is a function of frequency variations in said first-mentioned output signal.

19. A method of analysing variations in the motion of a rotary assembly substantially as described hereinabove with reference to Figures 1 to 3 optionally as modified in accordance with any of Figures 4 to 7 of the accompanying drawings.

20. Apparatus for analysing variations in the motion of a rotary assembly substantially as described hereinabove with reference to Figures 1 to 3 optionally as modified in accordance with any of Figures 4 to 7 of the accompanying drawings.

Amendments to the claims have been filed as follows

CLAIMS

1. A method of analysing variations in the motion of a rotary assembly, the method comprising repeatedly detecting the clearance between a discrete rotating element of said assembly and a datum, generating clearance signals which are a function of said clearance, analysing said signals to derive frequency components attributable to such variations, and deriving information about such variations from the phase and/or amplitude of said frequency components, wherein a multiplicity of successive digital signals are generated as a discrete rotating element of said rotary assembly moves past a datum position, each digital signal being a function of the instantaneous distance between that discrete rotating element and said datum position, and said clearance signal is derived from said digital signals.

2. A method according to Claim 1, wherein a further multiplicity of successive digital signals are generated as a further discrete rotating element of said rotary assembly moves past said datum position or as the first-mentioned discrete rotating element moves past a further datum position and a further clearance signal which is a function of the clearance of said further discrete element from said datum position or the clearance of said first-mentioned discrete element from said further datum position is generated from said further multiplicity of digital signals.

3. A method according to Claim 2 wherein both said clearance signals are analysed to derive said frequency components.

4. A method according to Claim 3 wherein said discrete rotating elements and/or datum positions are spaced apart in the axial direction.

5. A method according to any of Claims 1 to 4 wherein said clearance signal is derived by fitting a function of predetermined form to said digital signals and then determining a peak amplitude of the function.

6. A method according to Claim 5 wherein said function of predetermined form is a polynomial of predetermined order.

7. A method according to Claim 6 wherein said function of predetermined form is a polynomial having predetermined coefficients.

8. A method according to Claim 6 or Claim 7 wherein said polynomial is a fourth order polynomial.

9. A method according to any preceding Claim wherein orbiting or shaft bending motion of the rotary assembly is detected.

10. A method according to any of Claims 1 to 9 wherein bending of said discrete element is detected.

11. A method according to any preceding Claim wherein said clearance signal is generated by a capacitive probe.

12. A method according to any preceding Claim wherein a frequency modulated signal is generated whose frequency is a function of the instantaneous distance between its rotating element and datum, and frequency variations in said frequency modulated signal are detected by a phase-locked loop detector, said clearance signal being derived from an output signal of said detector.

13. A method according to any preceding Claim wherein said rotary assembly is a turbine assembly.

14. Apparatus for analysing variations in the motion of a rotary assembly, the apparatus comprising a probe means arranged to repeatedly detect the clearance between a discrete rotating element of said rotary assembly and a datum and to generate clearance signals which are a function of said clearance, Fourier transform analysing means responsive to such signals to derive frequency components attributable to such variations, and processing means arranged to derive information about such variations from the phase and/or amplitude of said frequency components, said apparatus including digital sampling means arranged to generate a plurality of digital signals which are a function of the instantaneous distance of a discrete rotating element of said rotary assembly from the probe means and digital processing means arranged to derive said clearance signal from said digital signals.

15. Apparatus according to claim 14 wherein said digital processing means is arranged to derive said clearance signal from said digitial signals by fitting a function of predetermined form to said digital signals and then determining a peak amplitude of the function.

The Patent Office

21

Application No: GB 9609677.1
Claims searched: 1 to 21

Examiner: Mr A Oldershaw
Date of search: 28 August 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1N NCTD, NCTE, NCTL, NCTM, NCXB

Int Cl (Ed.6): G01B; G01H

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US5163334	(SIMONDS)	1,15 at least
X	US5144840	(GENERAL ELECTRIC) see e.g. col.2 ll.58-66	1,12 at least
X	US5010494	(N.C. STATE UNIVERSITY) see e.g. col.6 ll.27-43	1,15 at least
X	US4607529	(MOREY)	"
X	US4482859	(S.N.E.C.M.A.) see col.1 ll.43-64; col.3 l.65 - col.4 l.11	1,12-14 at least
X	US4352293	(HITACHI)	1,15 at least
X	US3938394	(IRD MECHANALYSIS) see figs. 7,13	1 at least
X	US3488581	(FOSTER) see col.5 ll.48-57; col.8 ll.23-36	1,12 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.